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GENERAL THEORY OF SIGNALS AND GENERAL
THEORY OF AUTOMATIC PROCESSES

[Comment and Summary: This report gives in full an article by M. S. Neyman, active member of VNORiE (All-Union Scientific and Technical Society of Radio Engineering and Electric Communications, was published in Radiotekhnika, Vol 10, No 5, 1955. The article discusses the bases for establishing two disciplines of a general character: (1) the general theory of signals, and (2) the general theory of automatic processes. It defines the two disciplines, formulates their general outlines, their relation to each other, and emphasizes their importance to modern radio engineering and electronics.

A recent issue of the Journal Radiotekhnika (No 5, 1954) carried an interesting article by A. A. Kharkevich, in which the main points of the general theory of communications were formulated clearly and in sequence. In view of the importance of the problems which he touched upon, it is essential to undertake a further discussion of them.

It appears to us that, in addition to the general theory of communications (or information theory), whose scope and content were outlined in the above-mentioned work, there is a need to examine as well the considerably broader discipline which can be called the general theory of signals.

The concept of communication as the transmission of messages, even if remote control is included here, does not encompass a number of methods being used at the present time for reception of signals which are governed by the same or related general laws and which therefore should be included in the general theory.

At present, there exist two main types of use of signals. Accordingly, signals are divided into two main categories.

Signals of the first category can be called direct, being understood as those signals which convey definite messages or actions from a transmission point, as in telegraphy, telephony, television, remote control, etc.

The second type of signals comprises "sonding" signals, which are dispatched from the transmission point without any information content and are usually periodic functions of time. The useful factor is the variations (distortions) of the sonding signals which occur when the signals are propagated and which permit information to be gained concerning the medium (or actions with respect to the medium) in which the signals are propagated from the moment of their transmission to the moment of their reception. These useful signal distortions can have the character of change in shape; change in propagation direction due to reflection, scattering, and refraction; rotation of the plane of polarization; change in the type of wave; etc.

Sonding signals are used, as is known, in investigations of the ionosphere, in radar, in radioastronomy, in some radio navigation systems, etc.

Questions concerning distortions of sonding, as well as direct, signals are among the chief problems of the general theory of signals.

The existance of other categories of signals should also be noted: natural signals, in particular of atmospheric and astronomical origin; those of a different type of radiation used for passive direction finding; and some others. Naturally, all these cases should also be included in the general theory of signals.

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A second essential circumstance which is of importance in determining the content of the general theory of signals is the fact that each signal represents a definite action, coded in some form or other, which it can exert on some object. The distinctive feature of signals lies in the fact that they do not produce an action directly by means of energy, but rather they only control local energy sources or act on human sense organs.

There is a close relationship between the most suitable form for signals (as well as their effectiveness (economy) and reliability of action) and the nature of the sensers or amplifiers on which they are designed to act. Therefore the theory of signals can not be limited to the study of a "communications system from the message at its input to the message of its output only."

For example, in the study of problems of telephone or television systems signals it is impossible to treat signals without considering the physiological properties of the ear and eye. Similarly, research on radar systems employing visual indication can not be disassociated from problems concerning the properties of indicator tubes and the properties of the human eye; and it is impossible to carry research problems on artistic transmissions in radio broadcasting and television to the end without taking into account certain esthetic considerations.

A signal is not an independent creation: its properties are completely related to, and dependent on, the nature of the amplifying or sensing systems on which it must act, and also on the nature of those actions which it transmits in coded form.

The following auxiliary problems should also be included in the general theory of signals: systems guaranteeing secrecy of transmission (absolute and relative); the use of signals for synchronization and phasing; problems of resolving powers; the theory of active and passive identification; problems connected with the presence of responders and relay lines and circuits; problems of artificial noise and distortion; and others.

The general theory of signals, as understood in the sense indicated above, can be defined as the general theory which treats of the properties of signals (as well as signaling and communications systems) irrespective of the concrete energy nature of signals. In this relation, a signal is understood as any transient (in the partial case, also periodic) process capable of being propagated, i.e., of being shifted in space and time, and designed not for direct energization of action with respect to any objects, but for control of local energy sources or for action on human sense organs.

The general theory of signals should include, first of all, the following divisions: general problems; the theory of ideal transmission of signals; problems of simultaneous transmission of signals; the theory of signal distortions; and the theory of noise.

Systems which utilize signals -- for example, communications lines or remote control lines -- are circuits made up of elements which act upon one another in series. As such, it is characteristic that among the actions being transmitted along the circuit there are those which have a control function. These are actions which are executed by signals. Control actions do not have a direct energizing effect on subsequent elements of the circuit: this effect is produced by local energy sources, which the signals merely control.

The general theory of signals is closely bound up with the properties of these circuits, which can be called control circuits.

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Control loops possess a number of new properties which control circuits lack. These properties are so important and so basic that the theory which studies processes in control loops and in systems of interacting control loops is a separate theory with a rich content and great independent value. Thus, as is also true in the case of the theory of signals, it is also possiblw here to develop a general theory which does not enter into the examination of concrete apparatus, but which studies the general laws, divorced from the concrete energy character of phenomena. This is the general theory of automatic processes.

The subject matter for study under the general theory of automatic processes should consist of all processes which take place in systems containing control loops. These processes include stability and instability phenomena, automatic regulation processes, processes in amplifiers and converters with negative and positive feedback, self-oscillation processes, and more complex processes occurring when a system contains several interacting control loops.

Although both theories -- the general theory of signals and the general theory of automatic processes -- are independent disciplines, there is a deginite relation between them, since they both deal with actions which control energy sources.

Both theories are general, divorced in some measure from the concrete energy character of the phenomena, and are therefore applicable to different fields. However, turning to an examination of their concrete applications, we must emphasize that their closest ties are with modern electronics, radio engineering, and electric communications engineering. Electromagnetic waves and free electrons are the most mobile forms of matter. They are the most suitable means both for the rapid transmission of signals and for the realization of fast-acting automatic processes.

Therefore, both the general theory of signals and the general theory of automatic processes are of fundamental importance to modern radio engineering and electronics. Both these theories must be considered as components of the basis for the theoretical fundamentals of radio engineering along with the special divisions of physics which treat of electromagnetic and electronic phenomena. This consideration has not elicited sufficient attention.

If we can turn to the history of radio engineering from the moment of its inception until today, we can note two basic lines of its development.

The first of these has involved increasing the range of radio communication, from several hundred meters (in the first demonstration by A. S. Popov) to communication with the antipodes and reception of signals reflected from the moon.

The second direction has been the employment of increasingly rapid processes: increasingly rapid signals, from telegraph to television; increasingly short cycles of oscillations from generators; increasingly rapid automatic processes, including modern electronic servo systems, fast-acting computers; etc.

Modern radio engineering and electronics comprise the base which in the greatest measure has exerted influence on the development of the theory of signals and the theory of automatic processes.

Conversely, the precise formulation of the content of these two theories, and their development as clearly defined and logically constructed disciplines, will substantially assist the further development of radio engineering and electronics.

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